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# National Beef Tenderness Survey–2015: Palatability and Shear Force Assessments of Retail and Foodservice Beef

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**Abstract:** Beef retail steaks from establishments across 11 US cities and beef foodservice steaks from establishments in 6 US cities were evaluated using Warner-Bratzler shear (WBS) force and consumer sensory panels. The average post-fabrication aging time of steaks at retail establishments was 25.9 d with a range of 6 to 102 d, and those from foodservice establishments averaged 31.5 d with a range of 3 to 91 d. The retail steaks with the lowest WBS value ($P < 0.05$) was the boneless top loin, compared to the top round steaks, which had the higher ($P < 0.05$) average WBS value. For the foodservice sector, top loin and ribeye steaks had the lowest ($P < 0.05$) WBS values, whereas the top sirloin represented the highest ($P < 0.05$) WBS values. The top blade retail steaks received among the highest consumer ratings ($P < 0.05$), whereas the top round and bottom round steaks received among the lowest ($P < 0.05$) consumer ratings for overall liking, tenderness liking, tenderness level, flavor liking, and juiciness liking. For the foodservice sector, the ribeye and top loin steaks were rated higher ($P < 0.05$) than top sirloin steaks for all consumer rating categories. The WBS values and sensory ratings were comparable to previous surveys, indicating no substantial changes in tenderness. Additional emphasis in improving the tenderness of top and bottom round steaks is necessary to increase consumer acceptability of these cuts.

**Keywords:** beef, consumer panels, market survey, tenderness, Warner-Bratzler shear force
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## Introduction

The 2015 National Beef Tenderness Survey (NBTS) is the fifth installment in a series of surveys conducted in the United States (Brooks et al., 2000, Guelker et al., 2013, Igo et al., 2015, Shackelford et al., 1991, Voges et al., 2007). These studies serve as a beneficial resource to the beef industry and consumers by providing consistent data on tenderness across the United States for the retail and foodservice sectors. Additionally, the ability to compare the most recent survey to historical data provides insight into the improvements, if any, the industry has made, as well as to identify additional variables that, once improved, will continue to increase consumer satisfaction in beef.

All previous NBTS have stated that retail cuts from the round continue to be less tender and have less desirable consumer sensory evaluations (Brooks et al., 2000, Guelker et al., 2013, Shackelford et al., 1991, Voges et al., 2007). In Guelker et al. (2013), a

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subset of steaks from the round were cooked using a moist-heat method instead of dry-heat, in an attempt to improve the tenderness of steaks from this region of the carcass. No differences were reported between Warner-Bratzler Shear (WBS) values using dry and moist heat cooking methods for the top round and bottom round. It is possible that WBS values did not differ because the same internal degree of doneness was used for both the dry and moist methods of round steak preparation.

The objectives of this study were to evaluate changes in tenderness from previous national surveys of US foodservice and retail steaks through the evaluation of WBS force and consumer sensory panels, and to collect aging, branding, product features, grade, and tenderization information from store visits and product packaging.

## Materials and Methods

Before starting the project, standardized protocols were established to ensure consistency in product selection and data collection for the following collaborating institutions: North Dakota State University, Oklahoma State University, Texas A&M University, Texas Tech University, University of Florida, and University of Missouri. Consumer panel procedures were approved by the Texas A&M Institutional Review Board for Use of Humans in Research (IRB2015–0393M).

### *Retail and foodservice product selection*

Retail cities were chosen based on previous survey locations to maintain affiliation while representing a broad geographical range, but were not selected or analyzed as the origin of the meat that was sampled. Cities included New York, NY; Philadelphia, PA; Los Angeles, CA; Denver, CO; Las Vegas, NV; Tampa, FL; Atlanta, GA; Kansas City, MO; Houston, TX; Chicago, IL; and Seattle, WA. Representatives of the National Cattlemen's Beef Association's retail marketing team assisted with identifying and obtaining permission from the retail chains surveyed.

Each city was sampled over a 12-mo period. In each city, 2 to 3 retail chains, representing at least one-third of the total area market share were selected, with 4 stores per chain being sampled. Thus, product was obtained from a total of 8 to 12 supermarket stores per metropolitan area. In addition, if a membership club retail store existed in a city and that club was not included in the one-third market share, one store of each club chain present was sampled. To accurately represent consumer demographics in a region, corporate retail contacts were asked to identify individual retail stores of their respective chain. Store managers were notified of the impending sampling visit dates, to allow coordination between each individual store and the university personnel responsible for sampling. In some circumstances, it was necessary to purchase products from stores that had not been contacted or who did not wish to participate in the full scope of the survey (e.g., access to back room, separate analyses of their information, etc.).

Within each store, brand names, product features, and grades of product available were recorded. Post-fabrication dates were recorded from locations that granted permission to access the back room. For each city, collaborators purchased steaks according to the following predetermined study protocol. For cuts purchased from the self-service case, the following number of steaks were targeted: 5 bottom rounds; 5 top blades; 9 ribeyes, bone-in; 9 top loins, bone-in; 9 T-bones; 9 Porterhouses; 9 top rounds; 14 ribeyes, boneless; 14 top loins, boneless; and 14 top sirloins. For cuts purchased from the full-service retail case, 5 steaks for all cuts was the target number; however, most full-service cases only had ribeye and top loin steaks. All retail cuts were shipped to Texas A&M University in insulated containers with refrigerant materials and were stored under refrigerated conditions (2 to 4°C) on arrival. Within 2 d after arrival, steaks were removed from store packaging and all information available including brand designation, marketing claims, enhancement with percentage solution added, and any other important features were recorded. Using a ruler, mean external fat trim was determined calculating the average of 3 different fat locations to represent the entire steak. Steak thickness also was measured with a ruler at three different thickness locations and an average was calculated. All steaks were identified individually and vacuum-packaged at approximately –46 kPa using an UltraVac (Model 2100-D; Kansas City, MO). Boneless steaks were packaged in 2.0 mil bags with an Oxygen Transmission Rate (OTR) of 3 to 6 [cc / ($m^2$/24 hr/1 atm) @ 23°F/0%RH] (Item No. B2620; Cryovac-Sealed Air Corp., Charlotte, NC). Bone-in steaks were packaged using 6.5 mil bone-guard bags with an OTR of 3 to 6 [cc / ($m^2$/24 hr/1 atm) @ 23°F/0%RH] (Item No. B4620TGM; Cryovac-Sealed Air Corp.). Following packaging, all steaks were stored frozen (–40°C).

The following retail cuts were sampled including corresponding Universal Product Codes (UPC; Industry-Wide Cooperative Meat Identification Standards Committee, 2003): Top Blade Steak (UPC 1144); Ribeye steak, lip-on, boneless (UPC 1203); Ribeye steak, lip-on, bone-in (UPC 1197); Top loin steak, boneless (UPC 1404); Top loin steak, bone-in (UPC 1398); T-bone steak

(UPC 1369); Porterhouse steak (UPC 1330); Top sirloin steak, boneless, cap-off (UPC 1426); Top round steak (UPC 1553); and Bottom round steak (UPC 1466).

Forty-percent of retail steaks were assigned to WBS force evaluation and the remaining 60% of retail steaks were identified for consumer sensory panels in a manner to ensure appropriate representation of each cut type and city. After freezing, steaks assigned to consumer sensory panels were sent to 1 of 5 collaborating universities with an effort to equally distribute the same number of each retail cut among the universities. Steaks were shipped overnight in insulated containers with refrigerant material to each designated university.

In 6 cities (Houston, TX; Dallas, TX; Tampa, FL; Denver, CO; Las Vegas, NV; Philadelphia, PA), collaborators also sampled 1 foodservice establishment. Due to lack of available product in Houston, Dallas was identified as a city within the same region and similar demographics to supplement the remaining steaks needed. Prime, Top Choice, Choice, and Select USDA (2016b) quality grades were collected, and USDA (2014) Institutional Meat Purchase Specifications (IMPS) descriptions were used for naming the following cuts: Ribeye roll steak, boneless (IMPS 1112); Top loin steak, boneless (IMPS 1180); and Top sirloin butt steaks, center-cut, boneless (IMPS 1184B). Post-fabrication times were recorded, along with brand designation, marketing claims, enhancement with percentage solution added, and any other important features. Steaks were shipped to Texas A&M University and handled in the same manner as described above for the retail cuts.

Foodservice steaks were vacuum packaged, using the previously described parameters, and frozen (–40°C). Texas A&M University personnel randomly assigned the steaks into equal groups for either WBS force evaluation or consumer sensory panels using a random number generator of Microsoft Excel. Foodservice steaks were shipped to the University of Missouri in the same manner as the retail cuts for all WBS force and consumer sensory panel evaluations.

## Cook methods

Steaks were thawed in a 4°C cooler for 48 h before cooking to assure complete thawing of samples of different sizes and thicknesses. All retail steaks were cooked on a grated, non-stick electric grill (Hamilton Beach Indoor/Outdoor Grill, Hamilton Beach Brands, Inc., Southern Pines, NC). The grills were preheated for 15 min to an approximate temperature of 177°C. Foodservice steaks were cooked on a Garland gas grill (Garland Commercial Ranges Ltd, Mississauga, Ontario, Canada) pre-heated before cooking to a surface temperature of approximately 232°C. Internal temperature was monitored with a thermocouple reader (Omega HH506A, Omega Engineering Inc., Stanford, CT) using a 0.02-cm diameter, copper constantan Type-T thermocouple wire. All steaks were flipped when the internal temperature reached 35°C and were removed once the internal temperature of the steaks reached 70°C. Foodservice steaks assigned to consumer panels were kept warm by placing them (approximately 20 min) in an Alto-Shaam oven (Model 100-TH, Alto-Shaam Inc., Menomonee Falls, WI). The total cook time was recorded for each individual steak and cooking yields were determined using the steak weights recorded before and after cooking. Cooked steaks destined for WBS force determination were placed on trays in a manner to avoid any overlapping, covered with plastic wrap, and placed in a cooler at 2 to 4°C for approximately 12 to 18 h. Cooked retail steaks assigned to consumer sensory panel were placed in a Alto-Shaam warmer (Model 750-TH-II, Alto-Shaam Inc.) set at 60°C for no longer than 20 min prior to serving panelists.

## Warner-Bratzler shear force

Steaks for WBS force were cooked in the same manner as consumer sensory panel steaks. To expose muscle fiber orientation, steaks were trimmed of visible connective tissue. Using a hand-held coring device, cores were removed parallel to the muscle fibers. Six 1.3-cm cores were removed from each major muscle in the steak. Six cores from the *M. longissimus lumborum* and 4 cores from the *M. psoas major* were used to uniformly sample T-bone and Porterhouse steaks. Cores were sheared once, perpendicular to the muscle fibers on a United Testing machine (United SSTM-500, United Calibration Corp. and United Testing Systems Inc., Huntington Beach, CA) at a cross-head speed of 200 mm/min using a 10.0 kg load cell, and a 1.02-cm thick V-shaped blade with a 60° angle and a half-round peak. The peak force (kg) needed to shear each core was recorded, converted to Newtons (N), and the average peak shear force of the cores was used for statistical analysis.

## Consumer panel

Consumer sensory panels were conducted at Texas A&M University, Oklahoma State University, Texas Tech University, University of Florida, University of Missouri, and North Dakota State University as described below. Panelists were recruited from surrounding communities by using email list serves and random telephone solicitation. Upon arrival to the sensory facility, a brief orientation was held to provide instructions for sample evaluation and ballot completion. Then, participants signed a consent form and completed a demographic questionnaire. Steaks were randomly assigned to serving days using a random number generator in Microsoft Excel, cooked as previously described, and served warm to panelists. Each panelist was provided with Nabisco Unsalted Tops Premium Saltine Crackers (Kraft Foods Global, Inc., East Hanover, NJ) and double distilled deionized water to use as palate cleansers between samples. Each panelist evaluated 8 samples comprised of two cuboidal (1.27 cm × 1.27 cm × cooked steak thickness) portions representative of each steak type (portions comprised largely of fat or heavy connective tissue were not utilized). A 4-min time delay occurred between each sample, except between the fourth and fifth sample, in which a 10-min break occurred to reduce sensory fatigue. Samples were characterized using a 10-point scale for overall like (10 = like extremely; 1 = dislike extremely), overall like of flavor (10 = like extremely; 1 = dislike extremely), overall like of tenderness (10 = like extremely; 1 = dislike extremely), level of tenderness (10 = extremely tender; 1 = extremely tough), overall like of juiciness (10 = like extremely; 1 = dislike extremely).

### *Statistical analysis*

Sensory panel and WBS force data for foodservice steaks and sensory panel data for retail steaks were submitted by the collaborating universities to Texas A&M University for data entry and analysis. Data were analyzed using SAS (SAS Inst. Inc., Cary, NC). Postmortem storage or aging times were calculated using PROC MEANS, and percentages of boxes with postmortem aging times less than 14 d were analyzed using PROC FREQ. PROC FREQ also was used to analyze the percentages of steaks stratified into previously defined tenderness classes (Belew et al., 2003, Guelker et al., 2013, Igo et al., 2015, Shackelford et al., 1991, Voges et al., 2007).

For the remaining data, least squares means were calculated using PROC GLM and separated using the PDIFF option, when appropriate, with an α-level ($P < 0.05$). Specifically, steak type was utilized as a main effect for steak measurements (steak thickness, steak weight, external fat thickness) and retail WBS force analyses. For retail consumer sensory panel data, collaborating university location and steak type were included in the model, and steak type effects were reported. Steak type, quality grade, and steak type by quality grade interaction were included in the model for foodservice WBS force and consumer panel data.

## Results and Discussion

### *Post-fabrication aging times*

Subprimal post-fabrication aging times at retail establishments averaged 25.9 d (Table 1), with a range of 6 to 102 d. The present survey resulted in the highest numerical post-fabrication aging time, as the previous surveys from Guelker et al. (2013), Voges et al. (2007), and Brooks et al. (2000) reported averages of 20.5, 22.6, and 19.0 d, respectively. Compared to previous work, the range of days of storage has narrowed, as Guelker et al. (2013) reported a range of 1 to 358 d. The mean percentage of subprimal cases aged less than 14 d was 9.1, which is lower than previous studies where Guelker et al. (2013), Voges et al. (2007), and Brooks et al. (2000), reported 35.7, 19.6, and 34.1, respectively. The average post-fabrication aging time for foodservice beef steaks in the present survey was 31.5 d with a range of 3 to 91 d. Guelker et al. (2013) reported a lower average of 28.1 d and a more narrow range of 9 to 67 d. While assessing cattle production and market conditions have not been objectives of NBTS, those factors may influence retail product costs, consumers' willingness to buy, and ultimately, inventory movement.

An important factor to note is the aging times recorded represent the post-fabrication storage or aging

**Table 1.** Postfabrication storage or aging times for subprimals audited in the cold storage facilities of retail stores and foodservice operations

| Item | No. of cases | Days | | | | Age < 14d, %[1] |
|---|---|---|---|---|---|---|
| | | Mean | SD | Min. | Max. | |
| Retail | | | | | | |
| Shoulder clod | 57 | 19.6 | 8.0 | 6 | 50 | 24.6 |
| Top blade | 9 | 26.4 | 6.4 | 13 | 34 | 11.1 |
| Ribeye boneless | 225 | 29.2 | 13.5 | 6 | 101 | 8.4 |
| Bone-in ribeye | 171 | 28.1 | 9.8 | 16 | 91 | 0.0 |
| Strip loin | 296 | 27.2 | 14.3 | 6 | 101 | 11.8 |
| Bone-in strip loin | 83 | 26.0 | 16.2 | 11 | 102 | 2.4 |
| Short loin | 92 | 24.0 | 10.7 | 7 | 55 | 19.6 |
| Top sirloin | 265 | 26.6 | 12.1 | 6 | 75 | 9.1 |
| Top round | 186 | 23.2 | 11.0 | 8 | 100 | 5.9 |
| Bottom round | 140 | 21.5 | 11.8 | 8 | 74 | 40.7 |
| Overall | 1524 | 25.9 | 12.7 | 6 | 102 | 11.9 |
| Foodservice | | | | | | |
| Ribeye | 21 | 32.2 | 18.1 | 3 | 84 | 14.3 |
| Top loin | 17 | 34.6 | 17.1 | 16 | 91 | 0.0 |
| Top sirloin | 17 | 27.6 | 11.4 | 4 | 46 | 11.8 |
| Overall | 55 | 31.5 | 16.0 | 3 | 91 | 9.1 |

[1]Percentage of subprimals that had a fabrication date that was fewer than 14 d from the time of observation at the retail or foodservice operation.

times, meaning the box date was recorded to calculate the value. The box date did not include the time carcasses were chilled in the plant before fabrication, packaging, and boxing. However, it is unlikely that carcasses were aged more than 4 d before fabrication occurred. Also, product turnover and stock rotation may differ based on retail store management styles.

### *Product information*

Approximately 34.5% of retail steaks were labeled with a store brand or some type of claim (data not reported in tabular form). This is a notable change compared to previous work, as Voges et al. (2007) reported that nearly half of retail cuts were identified for a packer program, while approximately 43% were labeled with a store brand. Additionally, (Guelker et al., 2013), reported 64% of retail steaks were labeled with a packer/processor and/or store brand. Retailers representing at least one-third of the total market share are updated constantly as the market fluctuates. Store closures and company mergers occur between each tenderness survey. The decrease in the percentage of steaks labeled with a store brand or additional claims may be reflective of a narrowing retail sector due to consolidation of companies and the overall increase in growth and presence of few companies. Average steak thickness, external fat thickness, and steak weights for retail and foodservice cuts can be found in Table 2. In Guelker et al. (2013), retail cuts from the rib and loin were reported as the thickest, whereas cuts from the chuck and round were the thinnest. In the present survey, the top blade steaks, representing a portion of the chuck primal, were similar to the thickness of the Porterhouse and top round steak ($P < 0.05$), which represent the loin and round, respectively. The thickest ($P < 0.05$) cut was the top loin steak, at 2.97 cm, whereas the thinnest ($P < 0.05$) retail cut was the bottom round steak at 1.92 cm. Steak thickness, external fat thickness, and steak weight for the top loin were all numerically similar to values reported by Igo et al. (2015), which is not surprising since 4 of the same cities were used in this study. In addition, external fat thickness is numerically higher in this study than the 2006 National Beef Market Basket Study (Mason et al., 2009), which also selected steaks from a majority of the cities included in this study. Interestingly, data from the 2016 National Beef Quality Audit (NBQA) show beef carcasses have higher quality grades and adjusted fat thickness measurements compared to the 2011 NBQA, which could contribute to increased external fat thickness on retail steaks (Boykin et al., 2017a, Boykin et al., 2017b).

Mean thickness of foodservice ribeye, top loin, and top sirloin steaks differed ($P < 0.05$) with means of 2.91, 2.80, and 2.47 cm, respectively. Differences in thickness among all 3 types of foodservice steaks is not an outcome Guelker et al. (2013) reported, as steak thickness across cuts in the 2010 NBTS were similar. Top sirloin steaks had a lower mean external fat thickness compared to the ribeye and top loin steaks, which is in agreement with data presented by Guelker et al. (2013).

**Table 2.** Least squares means ± SE for steak thickness, external fat thickness, and steak weights for steaks from retail stores and foodservice operations

| Source/steak | *n* | Steak thickness, cm | External fat thickness, cm | Steak weight, kg |
|---|---|---|---|---|
| Retail | | | | |
| Top blade | 102 | $2.30^{d}$ (± 0.06) | $0.21^{e}$ (± 0.02) | $0.18^{f}$ (± 0.01) |
| Ribeye, lip-on, boneless | 311 | $2.87^{b}$ (± 0.03) | $0.45^{c}$ (± 0.01) | $0.40^{c}$ (± 0.01) |
| Ribeye, lip-on, bone-in | 100 | $2.60^{c}$ (± 0.06) | $0.46^{bc}$ (± 0.03) | $0.51^{b}$ (± 0.01) |
| Top loin | 321 | $2.97^{a}$ (± 0.03) | $0.55^{a}$ (± 0.01) | $0.36^{d}$ (± 0.01) |
| Top loin, bone-in | 71 | $2.48^{c}$ (± 0.07) | $0.56^{a}$ (± 0.03) | $0.37^{cd}$ (± 0.02) |
| T-bone | 119 | $2.51^{c}$ (± 0.05) | $0.58^{a}$ (± 0.02) | $0.50^{b}$ (± 0.01) |
| Porterhouse | 79 | $2.43^{cd}$ (± 0.07) | $0.52^{ab}$ (± 0.03) | $0.55^{a}$ (± 0.01) |
| Top sirloin, boneless, cap-off | 307 | $2.79^{b}$ (± 0.03) | $0.25^{e}$ (± 0.01) | $0.39^{c}$ (± 0.01) |
| Top round | 105 | $2.28^{d}$ (± 0.06) | $0.07^{f}$ (± 0.02) | $0.55^{a}$ (± 0.01) |
| Bottom round | 86 | $1.92^{e}$ (± 0.06) | $0.37^{d}$ (± 0.03) | $0.29^{e}$ (± 0.01) |
| *P*-value | | < 0.0001 | < 0.0001 | < 0.0001 |
| Foodservice | | | | |
| Ribeye | 160 | $2.91^{a}$ (± 0.03) | $0.50^{a}$ (± 0.01) | $0.43^{a}$ (± 0.01) |
| Top loin | 136 | $2.80^{b}$ (± 0.03) | $0.47^{a}$ (± 0.02) | $0.35^{b}$ (± 0.01) |
| Top sirloin | 136 | $2.47^{c}$ (± 0.03) | $0.04^{b}$ (± 0.02) | $0.31^{c}$ (± 0.01) |
| *P*-value | | < 0.0001 | < 0.0001 | < 0.0001 |

[a–f]Least squares means in the same column and within the same steak source without common superscript letters differ ($P < 0.05$).

## Warner-Bratzler shear force

As seen in Table 3, the top round steak received the highest numerical WBS values (40.2 N), whereas the boneless top loin had the lowest numerical WBS values at 19.9 N ($P < 0.05$). Our results differ, numerically, from data reported from Guelker et al. (2013), where the bottom round steak had the highest numerical WBS value (31.2 N) and the top blade had the lowest numerical WBS value (21.5 N) compared to all other retail steaks. Guelker et al. (2013) reported the WBS value of the top round and bottom round steak as 29.8 and 31.2 N, respectively. These values increased, numerically, in the present survey as the top round and bottom round steaks increased to 40.2 and 36.4 N, respectively. Igo et al. (2015) evaluated bone-in and boneless top loin steaks and reported average WBS values of 26.8 and 25.1 N, respectively. Our data show an increase in tenderness for these 2 cuts compared to Igo et al. (2015), with WBS values of 22.9 and 19.9 N for bone-in and boneless, respectively.

In regards to WBS values for foodservice, the top loin steak had the lowest ($P < 0.05$) value at 24.6 N, compared to ribeye and top sirloin steaks, which were 29.6 and 29.4 N, respectively (Table 3). Guelker et al. (2013) reported top loin steaks to have the lowest numerical WBS value (25.8 N) followed by the ribeye and top sirloin with 27.3 and 30.2 N, respectively. Voges et al. (2007) reported lower WBS values for ribeye, top loin, and top sirloin foodservice steaks than those in the 2010 NBTS survey (Guelker et al., 2013), as well those in the present survey.

Tenderness categories developed by Shackelford et al. (1991) and Belew et al. (2003) are used to display threshold differences between retail and foodservice steaks in Table 4. Notably, our results showed an increase in the "very tender" category for both the boneless top loin (95.93%) and bone-in top loin steaks (88.46%) when compared to the 2010 NBTS boneless top loin (84.78%) and bone-in top loin steaks (71.74%). The distribution of the percentage of bottom round steaks representing the "very tender," "tender," "intermediate," and "tough" categories were 37.14, 31.43, 17.14, and 14.29, respectively. Guelker et al. (2013) reported similar findings, as the bottom round also represented the retail steak with the lowest percentage in the "very tender" category and the highest in the "tender," "intermediate," and "tough" categories. The top blade, boneless and bone-in top loin, T-bone, and Porterhouse steaks were found to have increased percentages in the "very tender" category compared to previous findings by Guelker et al. (2013). Contrarily, some cuts now have lower percentages in the "very tender" category than the 2010 NBTS, and as a result, were more widely distributed across the "tender," "intermediate," and "tough" categories. These cuts include the boneless and bone-in ribeye, top sirloin, top round, and bottom round steaks. Additionally, when compared to Guelker et al. (2013) the percentage of steaks in the "tough" category increased from 4.35 to 9.80% for the top round and from

**Table 3.** Least squares means and SE for Warner–Bratzler shear force values (N) of retail and foodservice steaks

| Source/steak | *n* | Mean | SE |
|---|---|---|---|
| Retail | | | |
| Top blade | 32 | 20.8$^{cd}$ | 4.5 |
| Ribeye, lip-on, boneless | 122 | 20.5$^{d}$ | 2.3 |
| Ribeye, lip-on, bone-in | 42 | 23.1$^{cd}$ | 3.9 |
| Top loin | 123 | 19.9$^{d}$ | 2.3 |
| Top loin, bone-in | 26 | 22.9$^{cd}$ | 4.9 |
| T-bone | 49 | 29.1$^{bc}$ | 3.6 |
| Porterhouse | 32 | 23.3$^{cd}$ | 4.5 |
| Top sirloin, boneless, cap-off | 129 | 22.8$^{cd}$ | 2.2 |
| Top round | 51 | 40.2$^{a}$ | 3.5 |
| Bottom round | 35 | 36.4$^{ab}$ | 4.3 |
| *P*-value | | < 0.0001 | |
| Foodservice | | | |
| Ribeye | 80 | 29.6$^{a}$ | 0.7 |
| Top loin | 68 | 24.6$^{b}$ | 0.8 |
| Top sirloin | 68 | 29.4$^{a}$ | 0.8 |
| *P*-value | | < 0.0001 | |

[a–d]Least squares means in the same column and within the same steak source without common superscript letters differ ($P < 0.05$).

**Table 4.** Percentage distribution of retail and foodservice steaks stratified into tenderness categories based on Belew et al. (2003)

| Source/steak | Very tender, WBS[1] < 31.4 N | Tender, 31.4 *N* < WBS < 38.3 N | Intermediate, 38.3 *N* < WBS < 45.1 N | Tough, WBS > 45.1 N |
|---|---|---|---|---|
| Retail | | | | |
| Top blade | 96.88 | 3.13 | | |
| Ribeye, lip-on, boneless | 91.80 | 5.74 | 1.64 | 0.82 |
| Ribeye, lip-on, bone-in | 85.71 | 9.52 | 4.76 | |
| Top loin | 95.93 | 3.25 | | 0.81 |
| Top loin, bone-in | 88.46 | 11.54 | | |
| T-bone | 95.92 | 2.04 | | 2.04 |
| Porterhouse | 96.88 | 3.13 | | |
| Top sirloin, boneless, cap-off | 86.05 | 10.85 | 3.10 | |
| Top round | 64.71 | 17.65 | 7.84 | 9.80 |
| Bottom round | 37.14 | 31.43 | 17.14 | 14.29 |
| Foodservice | | | | |
| Ribeye | 68.75 | 22.50 | 5.00 | 3.75 |
| Top loin | 89.71 | 8.82 | 1.47 | |
| Top sirloin | 69.12 | 23.53 | 5.88 | 1.47 |

[1]WBS = Warner-Bratzler shear force values.

5.26 to 14.29% for the bottom round, while percentage of "tough" boneless top loin steaks decreased from 2.17 to 0.081%. Also, some of the boneless ribeye and T-bone steaks fell into the "tough" category for this survey, but Guelker et al. (2013) and Voges et al. (2007) did not report any "tough" boneless ribeye or T-bone steaks.

Also, displayed in Table 4 are the foodservice percentage distributions stratified into tenderness categories. The top loin steak had the highest percentage, at 89.71, in the "very tender" category, whereas ribeye and top sirloin steaks in the same category were 68.75 and 69.12, respectively. Guelker et al. (2013) reported a lower percentage of top loin and top sirloin steaks in the "very tender" category, but a higher percentage of ribeye steaks. The ribeye steaks in the present survey became more distributed across all 4 tenderness threshold categories, with 3.75% reported in the "tough" category. Voges et al. (2007) reported the highest numerical percentage of each foodservice cut in the "very tender" category, as ribeye steaks represented 81.4%, top loin steaks at 96.6%, and top sirloin steaks at 73.7%.

Least squares means for WBS values for foodservice steaks stratified by USDA quality grade are found in Table 5. Steaks graded Prime had lower ($P < 0.05$) average WBS values compared to Top Choice, Low Choice, and Select grades. Guelker et al. (2013) also reported Prime as having among the lowest ($P < 0.05$) WBS values and Select and ungraded foodservice steaks had higher WBS values ($P < 0.05$). Our findings contradict those of Lorenzen et al. (2003) who reported differences between Top Choice, Low Choice, and Select.

**Table 5.** Least squares means and SE for Warner–Bratzler shear force values (N) for foodservice steaks stratified by USDA quality grade group

| USDA grade group | $n^1$ | Mean, N | SE |
|---|---|---|---|
| Prime | 56 | $24.6^b$ | 0.8 |
| Top Choice | 64 | $28.5^a$ | 0.7 |
| Low Choice | 48 | $30.3^a$ | 0.8 |
| Select | 48 | $30.3^a$ | 0.9 |
| *P*-value | | < 0.0001 | |

[a,b]Least squares means without common superscript letters differ ($P < 0.05$).

[1]Number of steaks.

## Retail consumer sensory evaluations

Least squares means for sensory panel ratings of retail steaks are displayed in Table 6. Consumers evaluated samples for overall liking, tenderness liking, tenderness level, flavor liking, and juiciness liking. Differences ($P < 0.0001$) were reported across all retail cuts, indicating consumer perceptions were dependent on the respective steak cut sampled. Top blade steak was given among the highest ($P < 0.05$) panelist ratings, whereas top round and bottom round steaks received the lowest ($P < 0.05$) panelist ratings across all attributes. Guelker et al. (2013) and Voges et al. (2007) reported similar results as top and bottom round steaks were among the lowest consumer ratings for each sensory attribute as well. Guelker et al. (2013) reported top blade steaks to have the numerically highest ratings for overall liking and Voges et al. (2007) found bone-in top loin

**Table 6.** Least squares means ± SE for sensory panel ratings[1] for retail steaks

| Steak | $n^2$ | Overall liking | Tenderness liking | Tenderness level | Flavor liking | Juiciness liking |
|---|---|---|---|---|---|---|
| Top blade | 67 | $6.9^a$ (± 0.2) | $7.5^a$ (± 0.2) | $7.7^a$ (± 0.2) | $6.5^{ab}$ (± 0.2) | $7.1^a$ (± 0.2) |
| Ribeye, lip-on, boneless | 167 | $6.8^a$ (± 0.1) | $7.0^b$ (± 0.1) | $6.9^{bc}$ (± 0.1) | $6.5^{ab}$ (± 0.1) | $6.4^b$ (± 0.2) |
| Ribeye, lip-on, bone-in | 55 | $6.6^{ab}$ (± 0.2) | $6.6^{cd}$ (± 0.2) | $6.6^{cd}$ (± 0.2) | $6.6^{ab}$ (± 0.2) | $6.1^{bc}$ (± 0.2) |
| Top loin, boneless | 188 | $6.9^a$ (± 0.1) | $7.0^{bc}$ (± 0.1) | $7.0^{bc}$ (± 0.1) | $6.7^a$ (± 0.1) | $6.5^b$ (± 0.1) |
| Top loin, bone-in | 38 | $6.8^a$ (± 0.2) | $6.8^{bcd}$ (± 0.2) | $6.8^{bcd}$ (± 0.2) | $6.8^a$ (± 0.2) | $6.4^{bc}$ (± 0.3) |
| T-bone | 67 | $6.6^{ab}$ (± 0.2) | $6.8^{bcd}$ (± 0.2) | $6.7^{cd}$ (± 0.2) | $6.5^{ab}$ (± 0.2) | $6.2^{bc}$ (± 0.2) |
| Porterhouse | 43 | $6.9^a$ (± 0.2) | $7.3^{ab}$ (± 0.2) | $7.3^{ab}$ (± 0.2) | $6.6^{ab}$ (± 0.2) | $6.5^{ab}$ (± 0.2) |
| Top sirloin, boneless | 168 | $6.4^b$ (± 0.1) | $6.6^d$ (± 0.1) | $6.5^d$ (± 0.1) | $6.2^b$ (± 0.1) | $6.0^{bc}$ (± 0.1) |
| Top round | 53 | $5.5^c$ (± 0.2) | $5.1^e$ (± 0.2) | $4.9^e$ (± 0.2) | $5.8^c$ (± 0.2) | $5.2^d$ (± 0.2) |
| Bottom round | 49 | $5.4^c$ (± 0.2) | $5.1^e$ (± 0.2) | $4.9^e$ (± 0.2) | $5.6^c$ (± 0.2) | $5.8^{cd}$ (± 0.2) |
| *P*-value | | < 0.0001 | < 0.0001 | < 0.0001 | < 0.0001 | < 0.0001 |

[a–e]Least squares means in the same column without common superscript letters differ ($P < 0.05$).

[1]Sensory panel rating scales: overall like (10 = like extremely; 1 = dislike extremely), overall like of tenderness (10 = like extremely; 1 = dislike extremely), level of tenderness (10 = extremely tender; 1 = extremely tough), overall like of flavor (10 = like extremely; 1 = dislike extremely), overall like of juiciness (10 = like extremely; 1 = dislike extremely).

[2]Number of steaks.

and T-bone steaks to have the highest numerical overall liking ratings. The present NBTS survey reported top blade, bone-in ribeye, boneless ribeye, boneless top loin, bone-in top loin, T-bone, and Porterhouse steaks received among the highest ($P < 0.05$) consumer ratings for overall liking. Top round and bottom round steaks received the lowest ratings across all sensory categories compared to all other retail cuts ($P < 0.05$). In addition, no significant differences between bone-in and boneless top loin steaks in regard to consumer sensory panelist ratings were reported. This differs from Igo et al. (2015), who reported bone-in top loin steaks to have lower consumer ratings compared to boneless top loin steaks.

### Foodservice consumer sensory evaluations

Table 7 contains least squares means for sensory panel ratings of foodservice steaks. Top loin and ribeye steaks received higher ($P < 0.05$) consumer sensory panel ratings compared to top sirloin steaks for all sensory rating categories. This differs from the 2010 survey by Guelker et al. (2013), who did not find differences between cuts for overall liking and flavor liking categories. Consumer sensory panel ratings of foodservice steaks stratified by USDA grade group are reported in Table 8. Differences ($P < 0.05$) were observed between USDA grade groups for tenderness level and tenderness liking ratings. However, USDA grade groups did not differ ($P > 0.05$) for overall liking, flavor, or juiciness liking, indicating tenderness as the only factor consumers could identify for differences between grade groups. Least squares means for sensory panel ratings of ribeye, top loin, and top sirloin steaks stratified by USDA grade group are reported in Tables 9, 10, and 11, respectively. For foodservice ribeye steaks, Prime received the highest numerical consumer sensory panel ratings for overall liking, tenderness liking, and juiciness liking. In regards to tenderness level ratings, Prime was rated higher ($P < 0.05$) than all other grades. Similarly, Guelker et al. (2013) reported Prime ribeye steaks to have numerically higher consumer ratings for overall liking, tenderness liking, tenderness level, and juiciness liking when compared to other grades. Voges et al. (2007) reported a difference in consumer preference for flavor liking, as consumers scored Select ribeye steaks highest for flavor liking compared to all Prime, Top Choice, and Low Choice ribeye steaks. For the present study, differences ($P < 0.05$) between grades were seen for boneless top loin steaks in the tenderness level category only (Table 10). Although the consumers distinguished a difference in tenderness level, they rated all grades of top loin steaks similarly ($P > 0.05$) when evaluating overall lik-

**Table 7.** Least squares means ± SE for sensory panel ratings[1] for foodservice steaks

| Steak | $n^2$ | Overall liking | Tenderness liking | Tenderness level | Flavor liking | Juiciness liking |
|---|---|---|---|---|---|---|
| Ribeye | 79 | $7.0^a$ (± 0.1) | $6.9^a$ (± 0.1) | $6.8^a$ (± 0.2) | $7.0^a$ (± 0.1) | $6.4^a$ (± 0.2) |
| Top loin | 65 | $7.1^a$ (± 0.2) | $7.1^a$ (± 0.2) | $7.0^a$ (± 0.2) | $7.0^a$ (± 0.1) | $6.5^a$ (± 0.2) |
| Top sirloin | 67 | $6.5^b$ (± 0.2) | $6.3^b$ (± 0.2) | $6.2^b$ (± 0.2) | $6.5^b$ (± 0.1) | $5.5^b$ (± 0.2) |
| *P*-value | | 0.0100 | 0.0040 | 0.0063 | 0.0107 | < 0.0001 |

[a,b]Least squares means in the same column without common superscript letters differ ($P < 0.05$).

[1]Sensory panel rating scales: overall like (10 = like extremely; 1 = dislike extremely), overall like of tenderness (10 = like extremely; 1 = dislike extremely), level of tenderness (10 = extremely tender; 1 = extremely tough), overall like of flavor (10 = like extremely; 1 = dislike extremely), overall like of juiciness (10 = like extremely; 1 = dislike extremely).

[2]Number of steaks.

**Table 8.** Least square means ± SE for sensory panel ratings[1] for foodservice steaks stratified by USDA grade group

| USDA grade group | $n^2$ | Overall liking | Tenderness liking | Tenderness level | Flavor liking | Juiciness liking |
|---|---|---|---|---|---|---|
| Prime | 55 | 7.0 (± 0.2) | $7.2^a$ (± 0.2) | $7.2^a$ (± 0.2) | 6.8 (± 0.2) | 6.5 (± 0.2) |
| Top Choice | 62 | 6.9 (± 0.2) | $6.8^a$ (± 0.2) | $6.6^b$ (± 0.2) | 6.9 (± 0.1) | 6.2 (± 0.2) |
| Low Choice | 46 | 7.0 (± 0.2) | $6.8^a$ (± 0.2) | $6.7^{ab}$ (± 0.2) | 7.0 (± 0.2) | 6.1 (± 0.2) |
| Select | 48 | 6.5 (± 0.2) | $6.2^b$ (± 0.2) | $6.1^b$ (± 0.2) | 6.7 (± 0.2) | 5.7 (± 0.2) |
| *P*-value | | 0.0940 | 0.0030 | 0.0026 | 0.4934 | 0.1326 |

[a,b]Least squares means in the same column without common superscript letters differ ($P < 0.05$).

[1]Sensory panel rating scales: overall like (10 = like extremely; 1 = dislike extremely), overall like of tenderness (10 = like extremely; 1 = dislike extremely), level of tenderness (10 = extremely tender; 1 = extremely tough), overall like of flavor (10 = like extremely; 1 = dislike extremely), overall like of juiciness (10 = like extremely; 1 = dislike extremely).

[2]Number of steaks.

**Table 9.** Least squares means ± SE for sensory panel ratings[1] for foodservice ribeye steaks stratified by USDA grade group

| USDA grade group | $n^2$ | Overall liking | Tenderness liking | Tenderness level | Flavor liking | Juiciness liking |
|---|---|---|---|---|---|---|
| Prime | 20 | 7.3 ( ± 0.3) | 7.6$^a$ ( ± 0.3) | 7.7$^a$ ( ± 0.3) | 6.9 ( ± 0.2) | 7.0 ( ± 0.3) |
| Top Choice | 24 | 6.9 ( ± 0.2) | 6.9$^a$ ( ± 0.3) | 6.6$^b$ ( ± 0.3) | 7.0 ( ± 0.2) | 6.1 ( ± 0.3) |
| Low Choice | 15 | 7.2 ( ± 0.3) | 6.8$^{ab}$ ( ± 0.3) | 6.7$^b$ ( ± 0.3) | 7.4 ( ± 0.3) | 6.4 ( ± 0.3) |
| Select | 20 | 6.6 ( ± 0.3) | 6.1$^b$ ( ± 0.3) | 6.0$^b$ ( ± 0.3) | 6.8 ( ± 0.2) | 6.1 ( ± 0.3) |
| *P*-value | | 0.1809 | 0.0032 | 0.0012 | 0.3650 | 0.1089 |

[a,b]Least squares means in the same column without common superscript letters differ ($P < 0.05$).

[1]Sensory panel rating scales: overall like (10 = like extremely; 1 = dislike extremely), overall like of tenderness (10 = like extremely; 1 = dislike extremely), level of tenderness (10 = extremely tender; 1 = extremely tough), overall like of flavor (10 = like extremely; 1 = dislike extremely), overall like of juiciness (10 = like extremely; 1 = dislike extremely).

[2]Number of steaks.

**Table 10.** Least squares means ± SE for sensory panel ratings[1] for foodservice top loin steaks stratified by USDA grade group

| USDA grade group | $n^2$ | Overall liking | Tenderness liking | Tenderness level | Flavor liking | Juiciness liking |
|---|---|---|---|---|---|---|
| Prime | 19 | 7.3 ( ± 0.3) | 7.7 ( ± 0.3) | 7.7$^a$ ( ± 0.3) | 6.9 ( ± 0.2) | 7.2 ( ± 0.4) |
| Top Choice | 18 | 7.2 ( ± 0.3) | 7.0 ( ± 0.3) | 6.8$^b$ ( ± 0.3) | 7.2 ( ± 0.2) | 6.8 ( ± 0.4) |
| Low Choice | 16 | 7.0 ( ± 0.3) | 7.0 ( ± 0.3) | 6.9$^{ab}$ ( ± 0.3) | 6.9 ( ± 0.3) | 6.2 ( ± 0.4) |
| Select | 12 | 6.8 ( ± 0.3) | 6.6 ( ± 0.3) | 6.4$^b$ ( ± 0.4) | 6.9 ( ± 0.3) | 5.8 ( ± 0.5) |
| *P*-value | | 0.6487 | 0.0809 | 0.0479 | 0.8283 | 0.1211 |

[a,b]Least squares means in the same column without common superscript letters differ ($P < 0.05$).

[1]Sensory panel rating scales: overall like (10 = like extremely; 1 = dislike extremely), overall like of tenderness (10 = like extremely; 1 = dislike extremely), level of tenderness (10 = extremely tender; 1 = extremely tough), overall like of flavor (10 = like extremely; 1 = dislike extremely), overall like of juiciness (10 = like extremely; 1 = dislike extremely).

[2]Number of steaks.

**Table 11.** Least squares means ± SE for sensory panel ratings[1] for foodservice top sirloin steaks stratified by USDA grade group

| USDA grade group | $n^2$ | Overall liking | Tenderness liking | Tenderness level | Flavor liking | Juiciness liking |
|---|---|---|---|---|---|---|
| Prime | 16 | 6.6 ( ± 0.3) | 6.3 ( ± 0.4) | 6.1 ( ± 0.4) | 6.7 ( ± 0.3) | 5.2 ( ± 0.4) |
| Top Choice | 20 | 6.6 ( ± 0.3) | 6.6 ( ± 0.3) | 6.4 ( ± 0.3) | 6.6 ( ± 0.3) | 5.7 ( ± 0.4) |
| Low Choice | 15 | 6.7 ( ± 0.4) | 6.5 ( ± 0.4) | 6.4 ( ± 0.4) | 6.6 ( ± 0.3) | 5.6 ( ± 0.4) |
| Select | 16 | 6.1 ( ± 0.3) | 5.9 ( ± 0.4) | 6.0 ( ± 0.4) | 6.2 ( ± 0.3) | 5.3 ( ± 0.4) |
| *P*-value | | 0.5670 | 0.6059 | 0.7163 | 0.7708 | 0.7378 |

[1]Sensory panel rating scales: overall like (10 = like extremely; 1 = dislike extremely), overall like of tenderness (10 = like extremely; 1 = dislike extremely), level of tenderness (10 = extremely tender; 1 = extremely tough), overall like of flavor (10 = like extremely; 1 = dislike extremely), overall like of juiciness (10 = like extremely; 1 = dislike extremely).

[2]Number of steaks.

ing, tenderness liking, flavor liking, and juiciness liking. Guelker et al. (2013) and Voges et al. (2007) both reported no significant differences across grades and sensory panel ratings for top loin foodservice steaks. This differs from data reported by Lorenzen et al. (1999) who found differences between Top Choice and Select for overall liking. In regard to top sirloin foodservice steaks, there were no significant differences in the sensory ratings between grades (Table 11). This differs from the 2010 NBTS where ungraded top sirloins received the highest consumer ratings for overall liking, flavor liking, and juiciness liking when compared to other foodservice top sirloins in the Prime, Top Choice, Low Choice, and Select USDA grade groups (Guelker et al., 2013).

The fact that there are few differences in sensory panel ratings between USDA grade groups is potentially due to tenderization or enhancement procedures. According to USDA, over 2.7 million pounds of beef are mechanically tenderized each year (USDA, 2016a). Research has indicated both enhancement and blade tenderization of beef steaks as effective methods for increasing the tenderness of cuts that are prone to be less tender (King et al., 2009, Vote et al., 2000). Enhancement also has been reported to improve juiciness and flavor of beef strip loin steaks (Vote et al., 2000). It is possible that some of the foodservice steaks were tenderized or enhanced, and if so, then this would explain why few differences were noted in consumer sensory panel ratings across grades.

### *Overall assessment of beef tenderness*

Compared to the last 3 surveys, post-fabrication aging times increased for most steak types. This may be due in part to requirements of different branding programs or a change in managerial practices at the retail and processor levels. Conversely, the percentage of retail steaks labeled with a store brand or claim decreased from the previous 2 surveys.

With the exception of T-bone, top round and bottom rounds steaks, WBS values decreased numerically for retail cuts compared to the 2010 NBTS. From within the retail cuts that improved in WBS values from the 2010 survey, the boneless ribeye, boneless top loin, and top sirloin have decreased compared to the 2006 survey also, with the top sirloin doing so successively within surveys. Top loin and top sirloin foodservice steaks had improved WBS values and a larger presence in the "very tender" category compared to 2010.

Retail consumer sensory panel results were similar to previous tenderness surveys as top blade steaks received high numerical ratings, and top and bottom round steaks received among the lowest across all sensory categories evaluated. Foodservice consumer sensory panel ratings were also in agreement with previous findings.

In agreement with the previous tenderness surveys, cuts from the round still need more industry attention to decrease average WBS values and increase consumer acceptance. Consideration also must be given to the single method of cooking and final internal product temperature used for each of the cuts surveyed. Different cooking applications and degrees of doneness may be more advantageous, depending on the cut type. This underscores the importance of educating consumers of the most beneficial methods of cooking various beef steaks. Retail and foodservice establishments may use these data as a benchmark of US beef steak tenderness.

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